BLAST Workshop 2018 (7-9 May, LBNL, Berkeley, California, US)

Monday 07 May 2018 - Wednesday 09 May 2018

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Simulating particle interactions in transit with Impact-T

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Acceleration of a molecular hydrogen ion (H_2^+) beam in a radio-frequency quadrupole (RFQ) is proposed as the first stage of acceleration for a high-intensity continuous wave (CW) proton accelerator. This reduces the electric current in the RFQ by a factor of two, compared with accelerating the proton beam directly, and also allows existing designs for deuteron RFQs to be applied to molecular hydrogen ions, as the charge-to-mass ratio is almost identical. However, composite ions are susceptible to particle interactions that do not affect single ions, such as stripping of electrons and charge exchange. Such interactions may lead to production of secondary particles, which in high-intensity beams may cause damage to the accelerator and reduce the quality of the beam. In order to understand these effects, we have modified the Impact-T particle tracking code to include particle interactions during the tracking simulation. This code is also designed to be easily extensible to other interactions, such as collisions or break-up of heavier ions. Preliminary results and possibilities for future development will be discussed.

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Software for laser plasma interactions: open-source workbench in Weizmann Institute of Science

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The Center for Intense Laser Science at WIS is a new laboratory created around the 2x100TW laser system dedicated to laser plasma interaction, and, in particular, to the particles and radiation production in the laser plasma accelerators. In order to design and interpret the upcoming experiments a set of the proper numerical tools is needed, and today numerous open-source solutions exist to treat every aspect of this work. In this talk I will briefly review the software requirements for our research, and discuss the choice of the codes which was made for our numerical workbench. The particular place in this software collection is given to the components of BLAST toolkit – Particle-In-Cell codes WARP and FBPIC. At the end I will present an example of the laser-plasma driven free-electron laser source modeled from start to end with the open-source instruments.

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A deep-learning code of beam orbit correction on ciads surperconducting linac

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The MEBT of CIADS injector II has been under operation for several years successfully. It is made up of 7 quadrupoles, and there are 7 sets of adjoint Horizontal-Vertical correctors to correct the beam orbit. Five BPMs are used to obtain the beam horizontal and vertical positions, and the first one is located in front of MEBT. The beam position correction was mainly realized manually before, and the conventional method of response matrix was tested lately. This presentation focuses on the beam orbit correction test processing by deep learning. The beam positions were recorded while the correctors' current changed. Finally 17k items of events were acquired, 16k of which were used as training set, and 1k as test set. Neural networks, including back-propagation (BP) neural networks, convolutional neural networks (CNNs) and recurrent neural networks (RNNs), were set up to attempt at establishing the relationship between the current and the positions.

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WARP and ImpactT Simulations on Structured Electron Beams from Nano-engineered Cathodes

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WARP framework has promising extensive features for particle-in-cell simulations. Thus, simulations of the early-stage beam dynamics of the emission process from nano-engineered cathodes was carried out via WARP framework with our implementation of multi-photon-emission and field-emission process. Structured electron beams, emitted from such cathodes without azimuthal symmetries, require 3D-solver. Cathode-to-front-end beam dynamics, therefore, were simulated by using ImpactT with either 3D-solver or point-to-point N-body space charge solver. We explore the imaging of cathode pattern after acceleration and manipulation with focusing quadrupoles.

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Two-step Perfectly Matched Layer for Arbitrary-Order Pseudo-Spectral Analytical Time-Domain Method

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Numerical simulation of an electrodynamic system in empty space requires the implementation of open boundary conditions (BC) to terminate the solution of Maxwell's equations on the boundaries of the computational domain.
The Perfectly Matched Layer (PML) has become the method of choice for open BC with wave equations, as it is straightforward and relatively easy to implement, and offers very efficient and user-adjustable absorption rates. PMLs are most often employed with the Finite-Difference Time-Domain (FDTD) algorithm, which in its most common implementation offers second-order accuracy in space and time on Cartesian grids. Yet, simulations (including some class of electromagnetic Particle-In-Cell simulations) that require higher precision may resort to higher-order Maxwell solvers employing extended finite-difference stencils, or even to pseudo-spectral Maxwell solvers, for which a general, versatile and efficient formulation of the PML has been missing so far. We propose a novel "two-step" formulation of the PML that is applicable to a large class of Maxwell solvers including the arbitrary-order Pseudo-Spectral Analytical Time-Domain (PSATD) solver, which offers arbitrarily low numerical dispersion when increasing solver order and becomes dispersion-free at infinite order.
Analysis and numerical simulations demonstrate that the new formulation is as efficient as the standard PML formulation, both for the FDTD and the PSATD implementations.

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Ion Acceleration from Near-Critical-Density Plasmas via Magnetic Vortex Acceleration using 2D and 3D Warp/Picsar Particle-in-cell Simulations

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We explore laser-driven ion acceleration via the Magnetic Vortex Acceleration (MVA) scheme using 2D and 3D Warp+PICSAR particle-in-cell simulation codes. A high intensity ($I \sim 10^{23} W/\text{cm}^2$) and short pulse (30 fs) laser beam irradiates a Near Critical Density (NCD) hydrogen target. We find an optimum condition to maximize the ion energy from different target thicknesses and target densities.

The maximum ion energy in 3D is ~1/3 times lower than in 2D due to a smaller channel size in 3D and a different charge distribution between 2D and 3D. We also compare the results between the linear and the circular polarized laser beams in 3D simulations.

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Compiled Python module development for IMPACT interface

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We are planning to use IMPACT-Z for FRIB (Facility for Rare Isotope Beams) and developing it as FRIB-branch. In FRIB, IMPACT is used as the precise simulation tool which dedicate to simulate particle losses, nonlinear and space-charge effect for both offline and online analysis. Original IMPACT provides executable file only, therefore the user needs to access the simulation results through the file in disk and load input files including large 3D field data every time like in the case of parameter survey studies.
We have refactored IMPACT-Z to provide the compiled module for Python to support flexible inputs, direct output management, and iterative running in memory. It can be directly connected to the modern scientific tools typified by the parameter optimizers through the Python interface. In addition, the module can accomplish the interactive simulation process without losing computational efficiency because of the core part of the calculation is compiled by using general compiler. We report the code design of Python module of IMPACT and use cases in FRIB.

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WARP Particle-In-Cell Framework: A powerful tool for education and research for Korean graduate students at UNIST

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The Intense Beam and Accelerator Laboratory (IBAL) has been established in 2014 at Ulsan National Institute of Science and Technology (UNIST), Korea. Since then, the WARP Particle-In-Cell (PIC) framework has been actively used as a powerful tool for education and research for Korean graduate students. We have focused on three topics. 1) The first one is beam-plasma interaction for electron acceleration. The self-modulation instability (SMI) of electron beam and ionization injection schemes have been investigated. 2) The second topic is the motions of trapped charged particles in the solenoid magnet and the multi-ring electrodes. The beam which is injected into the solenoidal magnetic field will be trapped in the potential well generated by electrodes. After some beam manipulations, the trapped charged particles will be extracted from the trap with the help of electrostatic optics. 3) The third topic we have studied based on the WARP is high intensity, low and medium energy beam transports (LEBT and MEBT). Such beam transports are critical for the success of International Fusion Materials Irradiation Facility (IFMIF) and Accelerator Driven System (ADS). Using ionization module, LEBT with space-charge compensation effects can be studied. MEBT simulation is also in progress. In this talk, we will present the highlights of the WARP simulations on these three topics.

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Programmable Impact using python

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Physical research using simulation often involve a frequent change of input parameters and analysis of outputs. Python wrapper of IMPATz input/output provides such flexibility. It is also equipped with various tools of pre/post processing of IMPACTz data including optimization. Here, we illustrate these capabilities with few examples.

Summary:

We illustrate python wrapper of IMPACTz with few examples.

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